NuMI Primary Beam

November 4, 2004

NuMI Primary Overview

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- Design Features & Beamline Layout
- Status
- Start-up

NuMI Primary Design Parameters

Proton beam energy	120 GeV
Spill cycle time	>= 1.87 sec
Batch length	84 batches
Batch spacing	18.8 nsec (53 MHz)
Transverse emittance	15-20π mm-mr expected (95%) 500 π mm-mr maximum envelope
Momentum spread	2 x 10^{-4} δp/p 2σ expected 3 x 10^{-3} δp/p 2σ max
NuMI spill (pbar operation) NuMI spill (**no** pbar operation)	5 batches = 8.14 μsec 6 batches = 9.78 μsec
Maximum intensity	4 x 10^{13} ppp (protons/spill)
Total beam power	404 kW at maximum intensity

Extraction, Upstream Primary Constraints

- NuMI extraction design uses three kicker magnets to enhance cleanliness of extraction. Also the three Lambertson magnets are on two separate power supplies.
  - LAM60, then LAM61A&B. Reduced current for 1st magnet enables better clearance at MI Q608; then run 2nd & 3rd Lambertson at higher currents to reach essential vertical beam separation. This design choice taken as option of large aperture Q608 not available at the time

- Fringe field shielding installed on the six HV101 EPB dipoles to lower field at Recycler ring to ~ 2 Gauss max. Without this shielding, fringe fields are ~ 30-40 Gauss for worst case.
  - D. Jensen, R. Reilly – successfully tested for two magnets before shutdown; installation is complete.

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Beta & Eta Functions: Primary Beam Design

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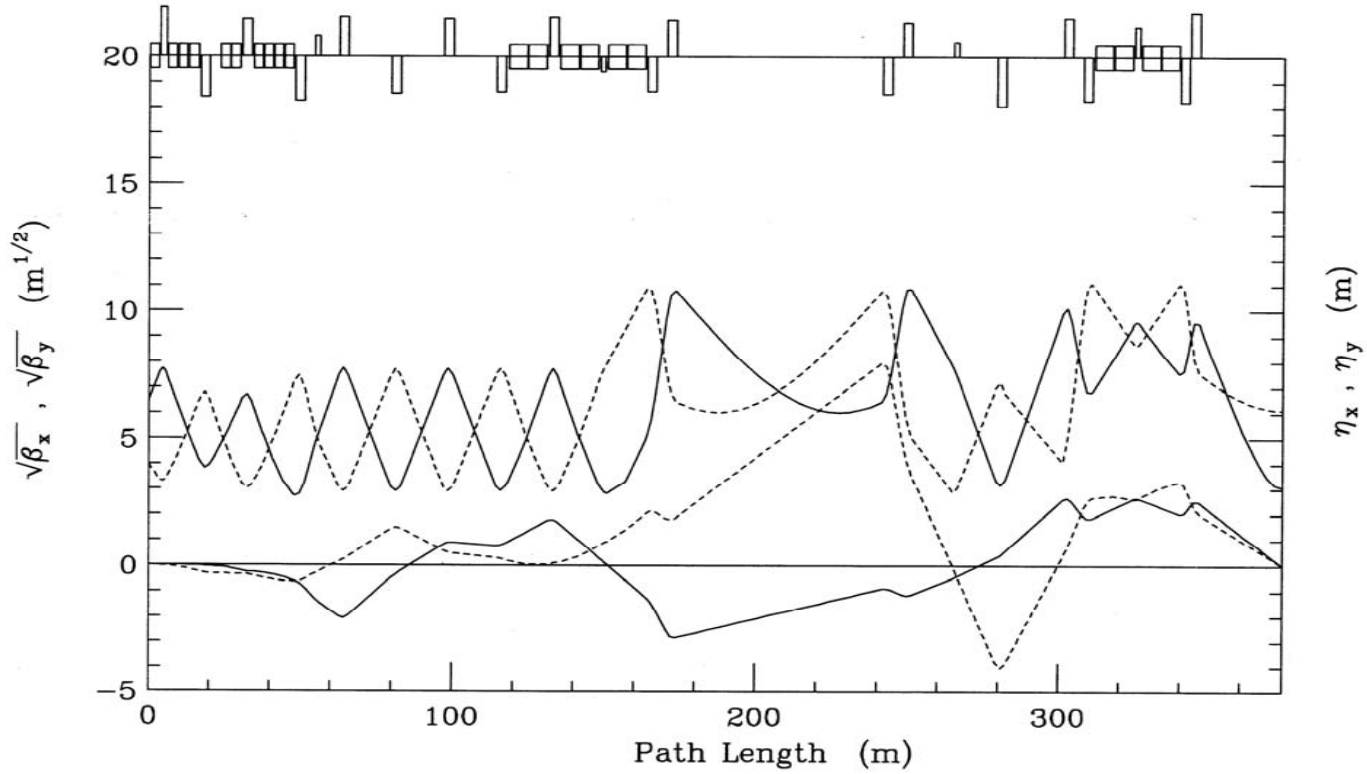

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Beam Transport & Aperture Clearance

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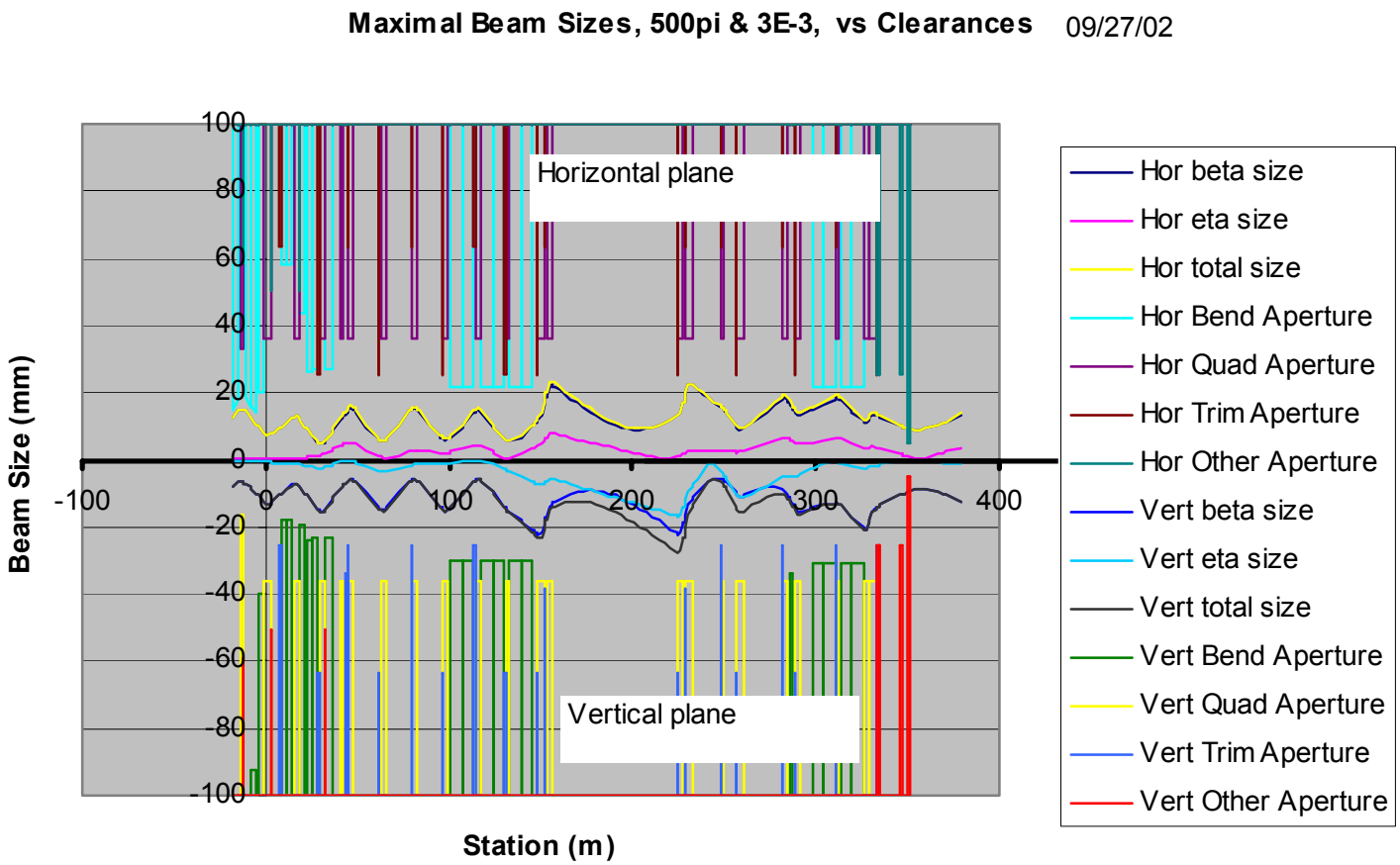

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MI-60, Extraction & Pretarget Enclosures

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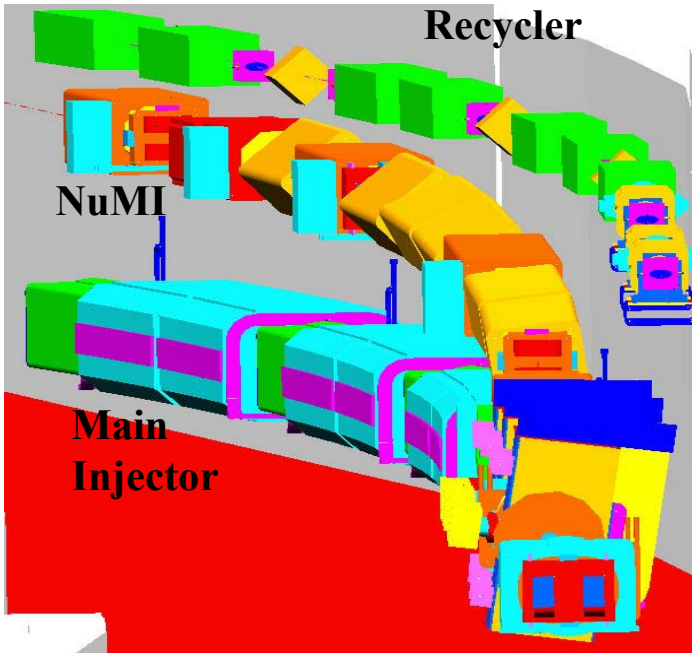
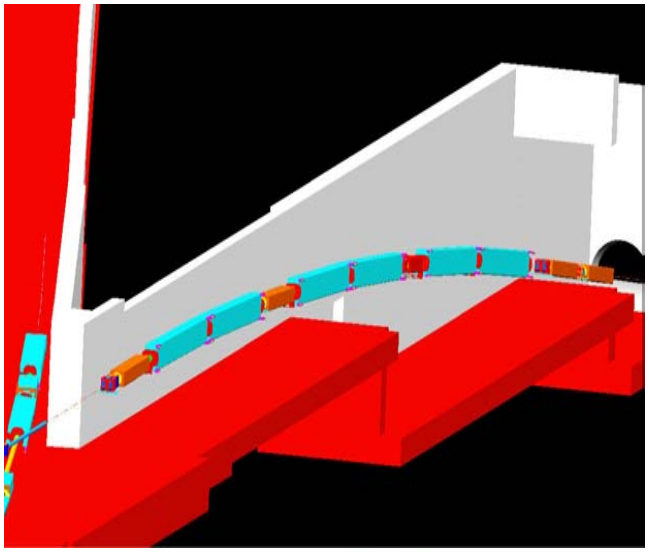
MI-60



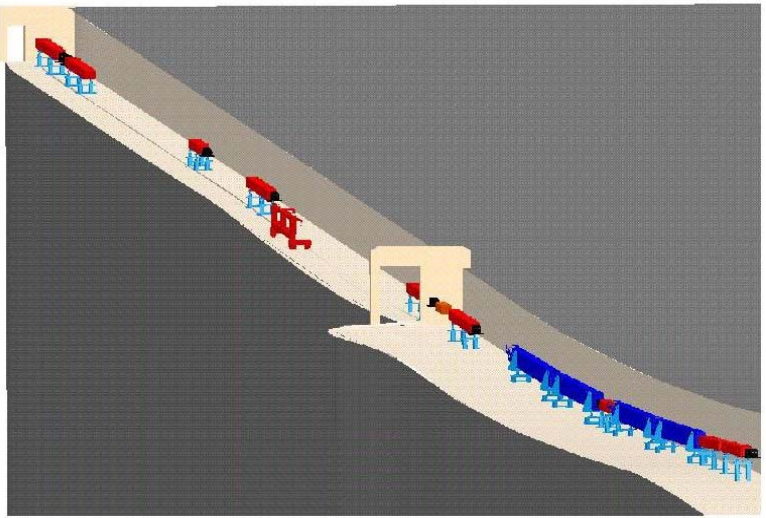


Extraction Enclosure

156 mrad down-bend

Pretarget Enclosure

98 mrad up-bend &
target focus



Targeting Requirements

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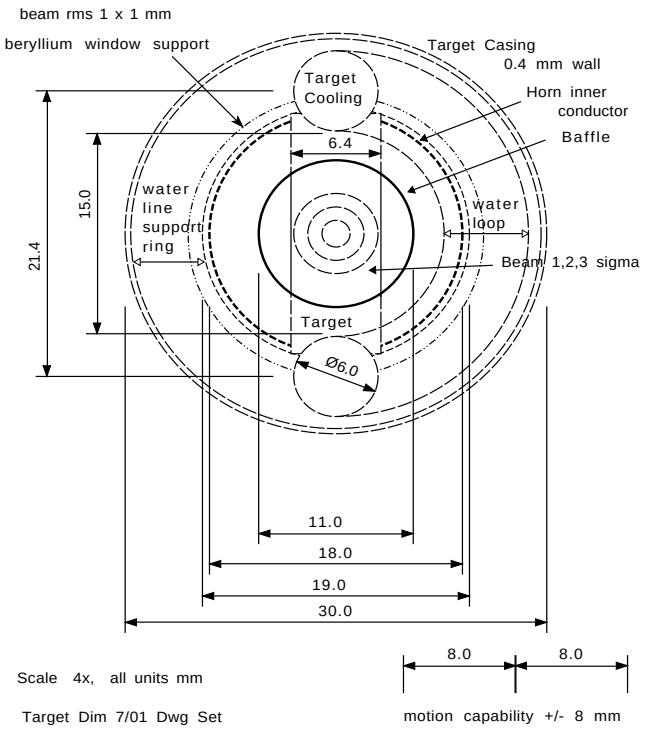
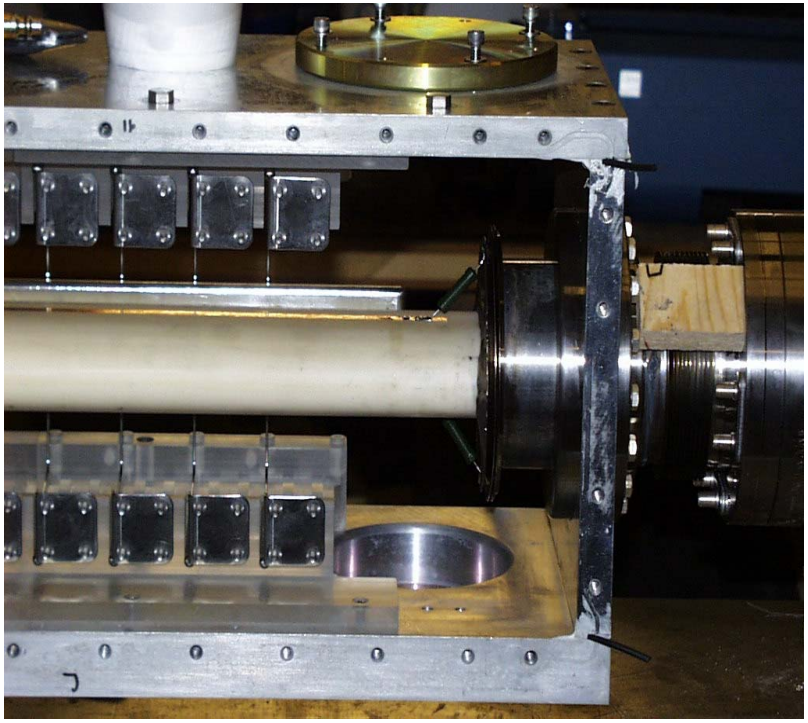


- Beam's eye view of target and baffle.
- Beam size on target:(σ) 1mm
- Position stability on target (σ) +/- 0.25 mm.
  - Minimize physics backgrounds
- Angle stability on target 60 μrad
  - Modest requirement for low energy beam

Kicker Construction



- 3 kicker Magnets
  - Each 2.2 m length
  - 60 kV max.
  - 4.0 kG-m at nominal 48 kV
- Magnets installed and pulsing in tunnnel; (tested to 57 kV)
- Tight specification for kicker waveform stability at flat-top [10 μsec length]
  - +/- 0.5%
  - Driven by beam targeting stability

NuMI Magnets and Correctors

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- 3 Kickers are new; " MI style" but with recovered ceramic beam tubes
  - « Vendor no longer available for new long ceramic tubes
  - « Share spare with MI
  - « New "long batch" power supply
- 3 Lambertsons are new; MI design
  - « Share spare with MI
- Refurbished dipoles [6 EPB's, 10 B2's, 2 SY Trims[and Quads [17 - 3Q120's and 4 - 3Q60's]
  - « All are ramped
  - « Separate power supply for each quad
- New MI design correctors of MI-H style - 19
  - « Rotated 90 deg. for vertical correctors
  - « 30 amp power supply; all ramped; external water cooling plates

NuMI Instrumentation

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- Beam Position Monitors - 24
  - « Detectors are MI-8 style split plate
  - « Electronics is digital receiver design – similar to Recycler
    - * Separate position and intensity readout for each batch
- Profile Monitors – 10
  - « New design: 5 micron Ti foils
  - « Built by U. Texas, Austin collaborators
- Intensity Monitors – 2
  - « Standard design toroids
- Beam Loss Monitors – 53
  - « TeV style sealed BLM's – 49
  - « Total Loss Monitors – 4
- Resistive Wall Monitor
- OTR Monitor – 1
  - « Being built along with Run II upgrade units

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Beamline Tour
MI-60 Region

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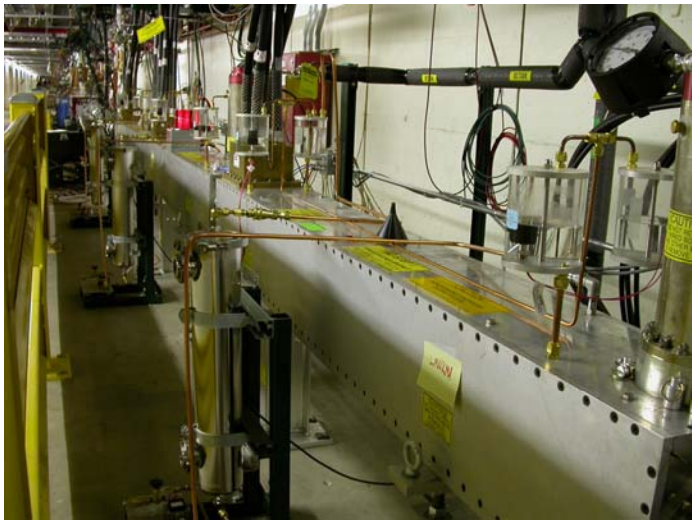

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NuMI "Stub" & Carrier Tunnel

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Lower Hobbit & Pretarget

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Current Status

- All components installed
- All component initial alignment complete
- Power supply testing in Pretarget area ongoing ~ Thursday thru Sunday each week. Power testing in MI area to resume as tunnel is secure
- Instrumentation checkout ongoing
- Vacuum hook-up is well advanced
- Final alignment ongoing
- Critical paths are final alignment and vacuum completion
- Have requested initial NuMI extracted beam 1st week of December!

NuMI Primary Beam Startup

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- NuMI beam system readiness at conclusion of current shutdown:
  - « Extraction and Primary beam ready for initial beam startup by 3 December
  - « Hadron Absorber ready for initial beam startup by 3 December
  - « Target Hall can accept low intensity beam in target out mode by 3 December. Full beam readiness in 2nd half January '05 [Jim's Talk]
- A high priority is to understand / resolve any significant NuMI extraction and primary transport issues while accelerator systems are still in start-up mode, and before pbars are stored in Recycler. NuMI extraction components and a major part of primary transport are in the MI / Recycler tunnel interlock region.

Requested NuMI low intensity beam start-up beginning Friday, 3 December

Initial Startup: Schedule & Intensity

- **Schedule:**
  - Request initial NuMI beam cycle in timeline for a total of four 12 hour shifts – one shift on each of Friday 3 Dec., Saturday 4 Dec. and two shifts on weekend of 10-12 Dec.
  - A meeting to review start-up plans with AD experts is scheduled for 11 Nov.
- **Initial Intensity:**
  - Based on Target Hall MARS results plan for integral NuMI intensity of < 1E14 protons in a 48 hour period
  - Operation for first weekend at 3E11 protons/pulse, with one NuMI cycle in a supercycle
  - Will then control beam switch for NuMI to transport beam only after previous pulse understood

Pre-beam Commissioning

- **We can – and will – establish readiness of systems for primary beam prior to first extracted beam pulses.**
- These include:
  - Magnet function & connection polarities
  - Power supply function / ramp parameters
  - Kicker & power supply function
  - Recycler shielding from EPB fringe fields
  - Instrumentation function and readout polarities
  - Beam Permit System [establish & test 1st limits for all but NuMI BLM's]
  - Control timing
  - Verify documentation capability – Profiles, BPM's, BLM's, Intensity
  - Main Injector beam suitable for extraction

Initial Beam Priorities

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- **Know that the basics work**
  - « Establish beam to the Hadron Absorber
  - « Verify kicker system function
  - « Verify instrumentation function
  - « Verify appropriate beam optics
  - « Verify alignment with beam
    - * Quads for acceptable corrector currents
    - * Limiting apertures for beam loss control
- Radiation safety verification for levels from first low intensity operation
- Understand any problems which can need tunnel access, and plan for solutions
- As part of initial commissioning process, fully utilize and verify function for beam permit and beam control systems
- Look toward full intensity Primary Beam commissioning as Target Systems are ready